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Effect of Environmental Pollutants PM2.5, CO, O_3 and NO_2, on the incidence and mortality of SARS-COV-2 in largest Metropolitan Cities, Delhi, Mumbai and Kolkata, India

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Abstract

Objectives: The Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) has developed a challenging situation worldwide. In India, the SARS-CoV-2 cases and deaths have been markedly increased. This study aims to evaluate the impact of environmental pollutants "particulate matter (PM 2.5µm), carbon monoxide (CO), Ozone (O3), and Nitrogen Dioxide (NO2) on daily cases and deaths due to SARS-CoV-2 infection" in Delhi, Mumbai, and Kolkata, India.

Methods: The day-to-day air pollutants PM2.5, CO, O3, and NO2 were recorded from the metrological web "Real-time Air Quality Index (AQI)." SARS-COV-2 everyday cases and deaths were obtained from the "Coronavirus outbreak in India Web". The PM 2.5, CO, O3, NO2, and daily cases, deaths were documented for more than one year, from the first case of SARS-CoV-2 in India, March 2, 2020, to March 15, 2021.

Results: Environmental pollutants CO, O_3, and NO2, were positively related to SARS-COV-2 cases and deaths. The findings further described that for each one-unit increase in CO, O3, and NO2 levels, the number of cases was significantly augmented by 0.77%, 0.45%, and 4.33%.

Conclusions: Environmental pollution is a risk factor to SARS-CoV-2 daily cases and deaths. The regional and international authorities must implement the policies to reduce air pollution and the COVID-19 pandemic. The findings can inform health policymakers' verdicts about battling the COVID-19 pandemic in India and globally by minimizing environmental pollution.

1.**Introduction**

Environmental pollution is the greatest problem of the 21st century, and it develops various hazardous situations and causes enormous harm to the biological ecosystem, weather conditions, human health, and living organism (Meo et al., 2020a). As per the World Health Organization report, nine out of ten people breathe polluted air, and it causes approximately seven million deaths worldwide every year (World Health Organization, 2020).

The air pollutants are consist of "dust, smoke, gases, carbon dioxide, carbon monoxide, nitrogen oxides, particulate matter, hydrocarbons, and other organic compounds" (Environmental Protection Agency US, EPA 2020; Pandey and Singh, 2019). Globally, urban areas are the leading causes of air pollution and are also affected by their toxic effects.

There is great discussion in the science community and health policymakers about environmental pollution and its association with the present pandemic due to "Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection also known as COVID-19 pandemic". This pandemic has developed a very hostile and challenging situation, and it has speedily involved the entire world with devastating consequences on human health and lives (Meo et al., 2020a). The COVID-19 pandemic involved the whole world. However, few countries are severely affected including the United States of America, England, Germany, Italy, and India.

India, a state in South East Asia, is the world's second highly populated, and the seventh-largest country. As per (Worldometer and United Nation data report, 2021), the total population of India is 1.39 billion, which is equivalent to 17.7% of the world population. The population density in India is 464 per Km^2. Moreover, 35.0% of the population resides in urban zones (Worldometer and United Nations collaboration report, 2021). Out of the top ten highly polluted cities globally, five cities are from India (Most polluted cities in the world, 2021). The large metropolitan cities face major air pollution allied health care challenges and a growing number of SARS-CoV-2 cases and deaths.

As per the World Health Organization report dated July 6, 2021, worldwide, the confirmed cases of SARS-CoV-2 are 183, 934, 913, and deaths 9,385, 022 (5.10%). However, in India alone, the number of confirmed cases is 30,619,932 (16.64%) and fatalities 403,281 (4.29%). These facts show that presently India is severely affected by the COVID-19 pandemic crisis.

The weather conditions and air pollution can increase SARS-CoV-2 cases in India and make these cities more prone to SARS-CoV-2 disease. The scientific literature highlights that environmental pollution is one of the leading causes of cases and deaths due to SARS-CoV-2 conditions (Meo et al., 2021b). This study aims to investigate "the effect of environmental pollution, particulate matter (PM 2.5), carbon monoxide (CO), Ozone (O3) and nitrogen dioxide (NO2) on daily cases and daily deaths due to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection" in three major cities, Delhi, Mumbai, and Kolkata.

2. Materials and Methods

The current study was piloted in the "Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia." India's three largest metropolitan cities, namely Delhi, Mumbai, and Kolkata, were selected for this study. These major cities of India are severely affected by environmental pollution and the SARS-CoV-2 cases and deaths.

2.1. Data Collection

The two research team members searched the metrological website "(Real-time Air Quality Index, AQI, 2021)" and found comprehensive everyday data about the required air pollutants. The daily air pollutants, "PM 2.5, CO, O3, and NO2, were noted from the metrological web (Real-time Air Quality Index, AQI, 2021)". The daily PM 2.5, CO, O3, NO2, were obtained from the first case of SARS-CoV-2 in these selected cities of India, March 2, 2020, to March 15, 2021 (over one year). Similarly, the members of the research team documented the SARS-COV-2 everyday incidence and mortality from the official web of India "(Coronavirus outbreak in India)." The SARS- CoV-2 day-to-day cases and deaths were collected from the publicly accessible databases web "Coronavirus outbreak in India Web". The everyday data on air pollutants, "PM2.5, CO, O3, and NO2", were obtained from the metrological web "(Real-time Air Quality Index, AQI, 2021)".

The day-to-day pollutants, "PM2.5, CO, O3, and NO2, and SARS-CoV-2" cases and deaths were documented from the date of appearance of the first case of "SARS-CoV-2" in the three cities of India, starting from March 2, 2020, to March 15, 2021, for Delhi; beginning from April 27, 2020, to March 15, 2021, for Mumbai; and March 5, 2020, to March 15, 2021, for Kolkata. A third member of the research team rechecked and re-confirmed the entire data.

2.2. Ethical Statement:

In this study, SARS-CoV-2 daily new cases and deaths, and "PM2.5, CO, O3 NO2" information was obtained from the "Coronavirus web, Coronavirus outbreak in India Web," And weather web "Real-time Air Quality Index (AQI)" publicly accessible databases, therefore, ethical approval was not required.

2.3. Statistical Analysis:

The data was examined using R-Core Team (2020), Vienna, Austria's language and environment foundation for statistical computing. "One-sample Kolmogorov- Smirnov test was used to test the assumptions of normal and Poisson distributions. Median quartiles were reported for non-normally distributed quantitative variables, cases, deaths, PM2.5, CO, O_3, and NO2. Spearman Rho Correlation was applied to assess the relationship between pollutant parameters with the number of cases and deaths at a 1% significance level. Poisson regression analysis was applied to predict the number of cases and deaths from pollutant parameters. An α=0.05 was considered as statistically significant".

3. Results

The ecological pollutants, "PM2.5, CO, O3, NO2, and SARS-CoV-2" cases and deaths were documented from the appearance of the first case of SARS-CoV-2 in India's three largest metropolitan cities, March 2, 2020, to March 15, 2021. The pollutants "PM2.5, CO, O_3, and NO2" were positively related to SARS-COV-2 cases and deaths in the three largest cities of India, Delhi, Mumbai, and Kolkata. The results further depicted that with one unit increase in CO, O3, and NO2 levels, the number of cases was significantly increased by 0.77%, 0.45%, and 4.33%. Similarly, for one unit increase in O3, and NO2 levels, the number of deaths was significantly increased by 1.1% and 2.89%, respectively. The findings further identified that NO2 was more toxic to increase cases and deaths in Delhi (Table 1, Figure 1).

Table 2 presented the Mumbai results, 1 µm increase in NO2; the cases increased by 0.84%. Likewise, with one unit upsurge in CO level, fatalities were increased by 0.98% (Table 2, Figure 2). Table 3 reveals the results for Kolkata, One unit increase in CO concentration increased SARS-CoV-2 cases and deaths by 14.32% and 10.36%, respectively (Table 3, Figure 3). However, there was no significant relationship identified between the other parameters.

4. Discussion

Presently, entire India is fronting significant challenges of air pollution and the COVID-19 pandemic. The largest cities in India, Delhi, Kolkata, and Mumbai, are sternly under the attack of the COVID-19 pandemic. This study explores the verdicts between air pollutants “PM2.5, CO, O3, NO2, day-to-day cases, and deaths due to SARS-CoV-2 infection”. There was a positive association between some ecological pollutants, CO, O3, NO2 levels, and SARS-CoV-2 cases and deaths. The higher the contaminants, are higher the number of cases and deaths.

The scientific literature recognized an association between ecotoxicity, genotoxicity, oxidative stress allied factors, and increased susceptibility to morbidity from respiratory infections. (Paital and Agrawal, 2020) found an association between PM2.5, NO_2 in air, and ACE-2 expression with the severity of SARS-CoV-2 infections. The literature further highlights that environmental conditions might link with the spread and occurrence of SARS-CoV-2 disease (Gautam et al., 2021). (Zheng et al., 2001) reported that the rise in PM2.5, PM10, and NO2 was related to an increase of 37.8%, 32.3%, and 14.2% COVID-19 cases, respectively. The outcome supports the hypothesis that atmospheric pollutants have an association with people's vulnerability to SARS-COV-2 infection.

(Bianconi et al. 2020) conducted a study on the COVID-19 pandemic situation in Italy. The authors found that PM2.5 has a considerable role in the increasing SARS-CoV-2 cases and deaths in Italy. Similarly, (Zhu et al. 2020) demonstrated a positive relationship between “PM2.5, PM10, CO, O3 with SARS-CoV-2” infection in China. Another study (Frontera et al. 2020) found PM2.5 and NO2 were linked to increased mortality due to SARS-CoV-2. Furthermore, in Germany, (Bilal et al. 2020) conducted a study on the ecological contaminants, weather conditions, SARS-COV-2 incidence, and mortality. The investigators concluded that PM2.5, O_3, and NO_2 have a substantial linkage with the COVID-19 pandemic.

In parallel to the above studies from China, Italy and Germany performed by (Zheng et al., 2001; Bianconi et al. 2020; Zhu et al. 2020; Frontera et al. 2020; and Bilal et al. 2020). Similarly, the present study findings demonstrate that SARS-CoV-2 cases and deaths were associated with PM 2.5, CO, O3, and NO2 in three different cities in India. It confirms that the studies published from various corners of the globe have similarities and associations with air pollutants and SARS-CoV-2 occurrence and deaths.

(Bashir et al., 2020) conducted a survey of environmental pollutants and the occurrence of SARS-

CoV-2. It was reported that “PM10, PM2.5, SO2, NO2, and CO” were related to COVID-19 epidemics. Similarly, (Chakrabarty et al., 2002) identified that long-term exposure to PM2.5 prone people to SARS-CoV-2. Another study (Paital, 2020) also found almost similar findings that atmospheric pollutants enhance the risk of the COVID-19 pandemic. It has also been reported that instant contact with PM2.5 may enhance infection vulnerability (Chen et al., 2020), as PM2.5 damages respiratory airways and potentially facilitating viral infections. Moreover, Long-term exposure to PM2.5 develops a chronic inflammatory problem mainly in unhealthy individuals (Conticini et al., 2020).

(Meo et al., 2020c) performed a study on the effects of “air pollutants PM2.5, CO, and O3 on the incidence and mortality of SARS-COV-2”. They observed that PM2.5 and CO were positively linked with SARS-COV-2 cases and deaths in San Francisco. Another study piloted by (Meo and colleagues 2021d) identified that “PM2.5, CO, and O3” positively correlate with SARS-CoV-2 everyday cases and deaths in London, UK. More recently, (Meo et al., 2021e) also reported that air pollutants “PM 2.5, CO, and O3” levels were significantly increased after the sandstorm, and these pollutants further increased the SARS-CoV-2 cases after the onset of the sandstorm. The findings demonstrate that environmental pollutants are involved in the spread and cause of the pandemic. Similarly, the current study findings show that SARS-CoV-2 rising cases and deaths were associated with air pollutants CO, O3, and NO2 in three different cities in India. These studies support the notion that air pollutants, PM2.5, CO, O3, and NO2, are linked to increasing SARS-CoV-2 day-to-day cases and deaths in three different metropolitan cities, Delhi, Mumbai, and Kolkata.

4.1. Pathway between air pollutants and pandemic

The present study interlinked the mechanisms to understand how environmental pollution cause SARS-COV-2 cases and deaths greatly. The lungs connect the human body to the environment and are highly vulnerable to various perilous pollutants and microorganisms (Michelle Galeas-Pena et al., 2019). It is a fact that air pollution impairs lung function and causes lung diseases (Meo et al., 2013f). Once lung functions are damaged, the body's immune system becomes weak and prone to bacterial and viral infections (Marsland et al., 2011). The most recent literature advocates that air pollution is a highly challenging and rising risk of severe illness or death among people with SARS-CoV-2 infection (Magazzino et al., 2020; Yao et al., 2020; Travaglio et al., 2021; Qu et al., 2020).

The literature highlights an association between the population's susceptibility to SARS-CoV-2 infection and mechanisms interlinked to alveolar angiotensin-converting enzyme 2 (ACE-2) (Paital and Agrawal 2020). The exposure of the lung to air pollutants causes lung injury due to “oxidative stress, macrophage disfunction, and a disrupted epithelial barrier” (Frontera et al., 2020; Zhu et al., 2020). It indicates that exposure to pollutants may upsurge susceptibility to lung diseases, thus SARS-CoV-2 affecting the large population. The literature demonstrates that environmental pollutants carry the virus, impair immunity, and are prone to pathogens and allied diseases (Zhou et al., 2020). Furthermore, air pollutants can cause “oxidative stress, inflammation, and lung damage.” These pieces of evidence support the notion that air pollutants could facilitate the spread of the SARS-CoV-2 virus (Zoran et al., 2020), promote entry into the respiratory system, and cause the severity of the disease and pandemic (Setti et al., 2020). The public, science community, and health officials must recognize the impact of air pollution on the COVID-19 pandemic and disease severity.

5. Study strengths and limitations

This is the first long-term, about a one-year duration-based study exploring the effect of air pollutants, “PM2.5, CO, O3, and NO2, on the day-to-day cases and deaths of SARS-CoV-2” infection in India's three largest metropolitan areas. We selected the largest cities of India which are affected by pollution and SARS-CoV-2 cases and deaths. The concentrations of PM2.5, CO, O3$_{3,}$ and NO2 and SARS-CoV-2 cases and deaths were recorded on a daily basis for a total period of about one year. A limitation of this study is that SARS-CoV-2 cases and deaths may be altered for other factors such as PM10, other pollutants, gatherings, temperature, and humidity.

6. Conclusions

The study findings conclude that environmental pollutants CO, O_3, and NO2, were positively related to SARS-COV-2 daily cases and deaths in the largest metropolitan cities, Delhi, Mumbai, and Kolkata, India. Air pollution is a risk factor to enhance SARS-CoV-2 daily cases and deaths. The environmental pollution protecting authorities should implement strategies and plan to curtail the environmental pollution and COVID-19 pandemic.

Declaration of competing Interest:

The authors declare that they have no known competing financial interests.

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References:

Bashir, M.F., Ma, B.J., Bilal, K.B., Bashir, M.A., Farooq, T.H., Iqbal, N., Bashir, M. Correlation between environmental pollution indicators and COVID-19 pandemic: A brief study in Californian context. Environ. Res. 2020; 187, 109652. doi: 10.1016/j.envres.2020.109652.

Bianconi, V., Bronzo, P., Banach, M., Sahebkar, A., Mannarino, M.R., Pirro, M. Particulate matter pollution and the COVID-19 outbreak: results from Italian regions and provinces Arch. Med Sci. 2020; 16, 985-992. doi: 10.5114/aoms.2020.95336.

Bilal, M.F.B., Benghoul, M., Numan, U., Shakoor, A., Komal, B., Bashir, M.A., Bashir, M., Tan, D. Environmental pollution and COVID-19 outbreak: insights from Germany. Air Qual Atmos Health. 2020; 3: 1-10. doi: 10.1007/s11869-020-00893-9.

Chakrabarty, R.K., Beeler, P., Liu, P., Goswami, S., Harvey, R.D., Pervez, S., Donkelaar A., Martin, R.V. Ambient PM2.5 exposure and rapid spread of COVID-19 in the United States, Sci. Total. Environ. 2020. 143391. https:// doi.org / 10.1016 /j.scitotenv.

Chen N., Zhou M., Dong X., Qu J., Gong F., Han Y. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet. 2020; 395:507–513.

Conticini E., Frediani B., Caro D. Can atmospheric pollution be considered a co-factor in an extremely high level of SARS-CoV-2 lethality in northern Italy? Environ. Pollut. 2020:114465.

Coronavirus outbreak in India Web" Available at https://www.covid19india.org/. Cited date April 20, 2021.

Environmental Protection Agency, US (EPA) 2021. Air Sensor Guidebook.Available: https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=519616. Cited date April 18, 2021.

Frontera, A., Cianfanelli L., Vlachos, K., Landoni, G., Cremona G. Severe air pollution links to higher mortality in COVID-19 patients: the "double-hit" hypothesis. J. Infect. 2020; 81(2):255-259.

Gautam, S., Samuel, C., Gautam, A.S., Kumar, S. Strong link between coronavirus count and bad air: a case study of India. Environ Dev Sustain. 2021;1-14. doi:10.1007/s10668-021-01366-4.

Magazzino, C., Mele, M., Schneider, N. The relationship between air pollution and COVID-19-related deaths: An application to three French cities. Appl Energy 2020; 279:115835.

Marsland, B.J., Königshoff, M., Saglani, S., Eickelberg, O. European Respiratory Journal 2011; 38 (3): 500-501; DOI: 10.1183/09031936.00103211.

Meo, S.A., Abukhalaf, A.A., Alomar, A.A., Alessa, OM, Wildfire and COVID-19 pandemic: effect of environmental pollution PM2.5 and carbon monoxide on the dynamics of daily cases and deaths due to SARS-COV-2 infection in San-Francisco USA. Eur Rev Med Pharmacol Sci. 2020a; 24 (19): 10286-10292. doi: 10.26355/eurrev_202010_23253.

Meo, S.A., Abukhalaf, A.A., Alomar, A.A., Alessa, O.M., Sami, W., Klonoff, D.C. Effect of environmental pollutants PM2.5, carbon monoxide, and ozone on the incidence and mortality of SARS-COV-2 infection in ten wildfire-affected counties in California. Sci Total Environ. 2021b; 757:143948. doi: 10.1016/j.scitotenv.2020.143948.

Meo, S.A., Abukhalaf, A.A., Alomar, A.A., Alessa, OM Wildfire and COVID-19 pandemic: effect of environmental pollution PM2.5 and carbon monoxide on the dynamics of daily cases and deaths due to SARS-COV-2 infection in San-Francisco USA. Eur Rev Med Pharmacol Sci 2020c; 24 (19):10286-10292. doi: 10.26355/eurrev_202010_23253.

Meo, S.A., Abukhalaf, A.A., Sami, W., Hoang, T.D. Effect of environmental pollution PM2.5, carbon monoxide, and ozone on the incidence and mortality due to SARS-CoV-2 infection in London, United Kingdom. Journal of King Saud University-Science. 2021d; 33 (3): 101373. doi.org/10.1016/j.jksus.2021.101373

Meo, S.A., Almutari, F.J., Abukhalaf, A.A., Alessa, O.M., Al-Khlaiwi, T, Meo, A.S. Sandstorm and its effect on particulate matter PM 2.5, carbon monoxide, nitrogen dioxide, ozone pollutants, and SARS-CoV-2 cases and deaths. Science of The Total Environment. 2021e; 148764. doi.org/10.1016/j.scitotenv.2021.148764.

Meo, S.A., Al-Drees, A.M., Al Masri, A.A., Al Rouq, F., Azeem, MA Effect of a duration of exposure to cement dust on respiratory function of non-smoking cement mill workers. Int J Environ Res Public Health. 2013f. 16;10(1):390-8. doi: 10.3390/ijerph10010390.

Michelle, Galeas-Pena., Nathaniel, McLaughlin., Derek, Pociask. The role of the innate immune system on pulmonary infections. Biol. Chem. 2019; 400 (4): 443-456.

Most polluted cities in the world: 2021. Available at https://smartairfilters.com/en/blog/25-most-polluted-cities-world-2020-rankings/ cited date April 20, 20201.

Paital, B., Agrawal, P.K. Air pollution by NO2 and PM2.5 explains COVID-19 infection severity by overexpression of angiotensin-converting enzyme 2 in respiratory cells: a review. Environ Chem Lett. 2020; 18:1-18. doi: 10.1007/s10311-020-01091-w.

Pandey, V.C., Singh, V. Exploring the Potential and Opportunities of Current Tools for Removal of Hazardous Materials From Environments. Phytomanagement of Polluted Sites, 2019; 501-516.

Qu G., Li X., Hu L., Jiang G. An imperative need for research on the role of environmental factors in the transmission of novel coronavirus (COVID-19). Sci. Technol. Environ 2020; 54 (7): 3730-3732.

Real-time Air Quality Index (AQI). Available at: https://aqicn.org/city/india/kolkata/fort-william/ Cited date April 12, 2021.

Setti, L., Passarini, F., De, Gennaro, G., Barbieri, P., Licen, S., Perrone, M.G., Piazzalunga, A. et. Potential role particulate matter in the spreading of COVID-19 in Northern Italy: first observational study based on initial epidemic diffusion. BMJ Open. 2020; 10 (9):e039338. doi:

Travaglio M., Yu Y., Popovic R., Selley L., Leal N.S., Martins L.M. Links between air pollution and COVID-19 in England. Environ. Pollut. 20201; 268:115859.

World Health Organization (WHO). Air pollution. Available at: https://www.who.int/health-topics/air-pollution#tab=tab. Cited date April 20, 2021.

World Health Organization (WHO). Coronavirus. Available at: https://covid19.who.int/. Cited date July 6, 2021.

World population. Available at: https://www.worldometers.info/world-population/india-population. cited date April 20, 20201

Yao, Y., Pan, J., Wang, W., Liu, Z., Kan, H., Qiu, Y., Meng, X., Wang, W. Association of particulate matter pollution and case fatality rate COVID-19 in 49 Chinese cities. Sci. Total Environ. 2020; 741:140396.

Zheng, P., Chen, Z., Liu, Y., Song, H., Wu, C.H., Li, B., Kraemer, M.U.G., Tian, H., Yan, X., Zheng, Y., Stenseth, N.C., Jia, G. Association between coronavirus disease 2019 (COVID-19) and long-term exposure to air pollution: Evidence from the first epidemic wave in China. Environ Pollut. 2021; 276:116682. doi: 10.1016/j.envpol.2021.116682.

Zhu, Y., Xie, J., Huang, F., Cao, L. Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China. Sci. Total. Environ. 2020; 727, 138704.

Zoran, M.A., Savastru, R.S., Savastru, D.M., Tautan, M.N. Assessing the relationship between surface levels of PM2.5 and PM10 particulate matter impact on COVID-19 in Milan, Italy. Sci. Total. Environ. 2020; 738, 139825. doi: 10.1016/j.scitotenv.2020.139825.

Tables:

Table 1. Poisson Regression for PM 2.5, CO, O3, and NO2 relation with the number of cases and deaths in Delhi.

Cases	Estimate(β)	Std. Error	Z Value	Exp(β)	Pr(>|Z |)
(Intercept)	6.469e+00	3.859e-03	1676.25	644.7784026	<2e-16 ***
PM 2.5	-1.282e-03	2.198e-05	-58.34	0.9987188	<2e-16 ***
CO	7.632e-03	6.422e-05	118.85	1.0076614	<2e-16 ***
O3	4.462e-03	4.145e-05	107.64	1.0044719	<2e-16 ***
NO2	4.240e-02	1.163e-04	364.63	1.0433136	<2e-16 ***

Deaths	Estimate(β)	Std. Error	Z Value	Exp(β)	Pr(>|Z |)
(Intercept)	2.5395135	0.0292915	86.698	12.6735034	<2e-16 ***
PM 2.5	-0.0002536	0.0001665	-1.523	0.9997464	0.128

CO	-0.0072579	0.0006331	-11.465	0.9927684	<2e-16 ***
O3	0.0109769	0.0002778	39.508	1.0110374	<2e-16 ***
NO2	0.0284741	0.0009546	29.828	1.0288834	<2e-16 ***

"Std. Error = Standard Error; β = Coefficient Estimates; Exp(β) = Exponentiated Values. ¥Controlled for temporal trends [date, day of week and weekends]. ⁎ Statistically significant at 5% level of significance".

Table 2. Poisson Regression for PM 2.5, CO, O3, and NO2 relation with the number of cases and deaths in Mumbai.

Cases	Estimate(β)	Std. Error	Z Value	Exp(β)	Pr(>|Z |)
(Intercept)	7.258e+00	3.127e-03	2321.333	1419.2734249	<2e-16 ***
PM.2.5	-8.541e-05	4.352e-05	-1.962	0.9999146	0.0497 *
CO	-4.739e-02	1.106e-03	-42.863	0.9537130	<2e-16 ***
O3	-1.123e-02	1.481e-04	-75.836	0.9888282	<2e-16 ***
NO2	8.338e-03	1.961e-04	42.530	1.0083733	<2e-16 ***

Deaths	Estimate(β)	Std. Error	Z Value	Exp(β)	Pr(>|Z |)
(Intercept)	4.4300126	0.0163669	270.670	83.9324706	<2e-16 ***
PM.2.5	-0.0055166	0.0003067	-17.987	0.9944986	<2e-16 ***
CO	0.0097129	0.0071987	1.349	1.0097602	0.177
O3	-0.0095591	0.0009256	-10.328	0.9904864	<2e-16 ***
NO2	-0.0171730	0.0012772	-13.446	0.9829736	<2e-16 ***

"Std. Error = Standard Error; β = Coefficient Estimates; Exp(β) = Exponentiated values. ¥Controlled for temporal trends,⁎Statistically significant"

Table 3. Poisson Regression for PM 2.5, CO, O3, and NO2 relation with the number of cases and deaths in Kolkata.

Cases	Estimate(β)	Std. Error	Z Value	Exp(β)	Pr(>|Z |)
(Intercept)	6.035e+00	5.466e-03	1104.18	417.8272092	<2e-16 ***
PM.2.5	-9.291e-04	3.178e-05	-29.24	0.9990713	<2e-16 ***
CO	1.338e-01	1.743e-03	76.77	1.1431811	<2e-16 ***
O3	-9.131e-03	3.367e-04	-27.12	0.9909102	<2e-16 ***
NO2	-2.144e-02	4.853e-04	-44.19	0.9787847	<2e-16 ***

Deaths	Estimate(β)	Std. Error	Z Value	Exp(β)	Pr(>|Z |)
(Intercept)	2.4827882	0.0349290	71.081	11.9746061	< 2e-16 ***
PM.2.5	-0.0005516	0.0002181	-2.528	0.9994486	0.0115 *
CO	0.0986167	0.0120042	8.215	1.1036431	< 2e-16 ***

O3	0.0093066	0.0022151	-4.201	0.9907366	2.65e-05 ***
NO2	0.0265807	0.0032796	-8.105	0.9737695	5.28e-16 ***

"Std. Error = Standard Error; β = Coefficient Estimates; Exp(β) = Exponentiated values. ¥Controlled for temporal trends,⁎Statistically significant"

Figures

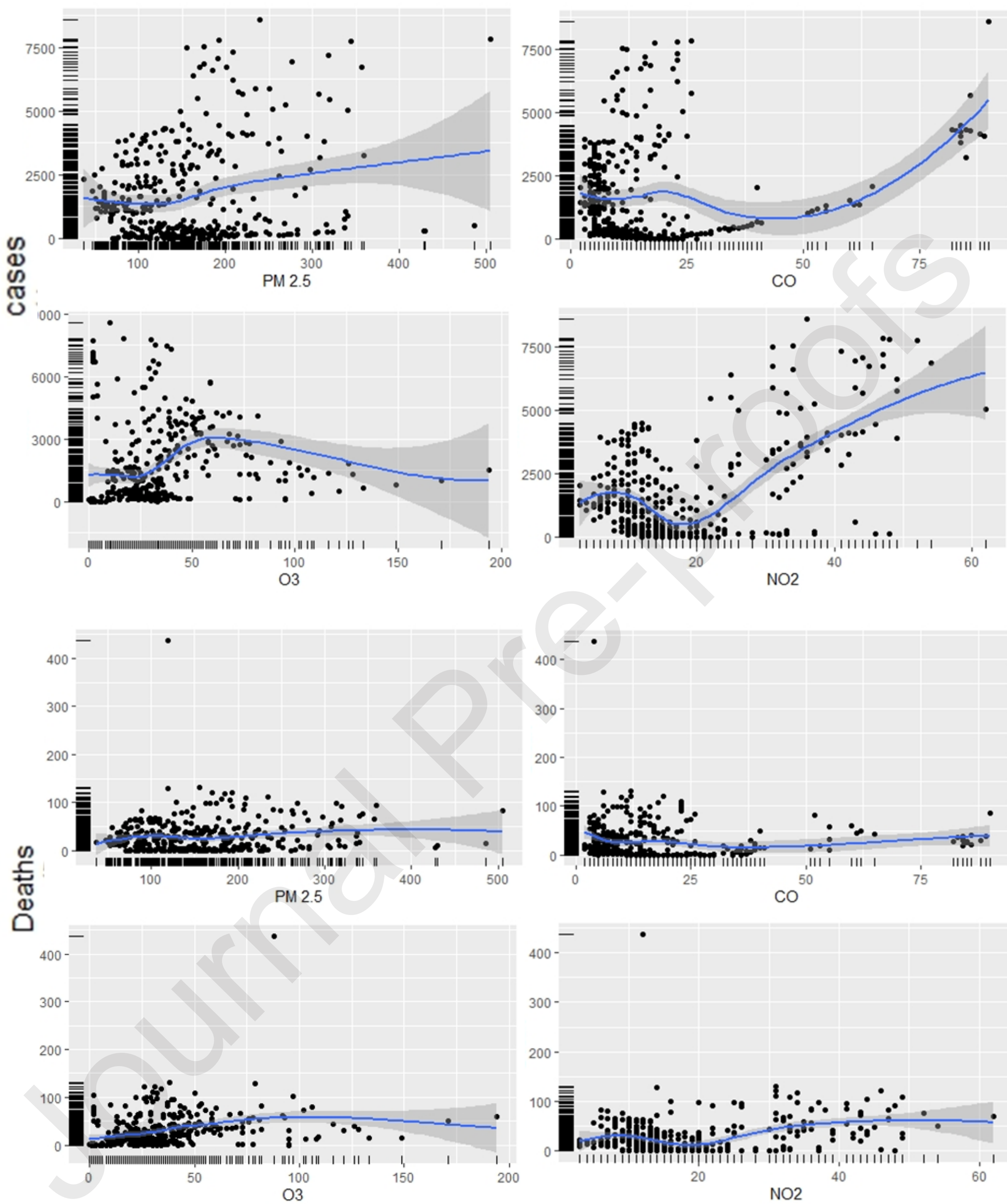

Fig. 1. Association of PM2.5, CO, O3 and NO2 with SARS-CoV-2 cases and deaths in Delhi.

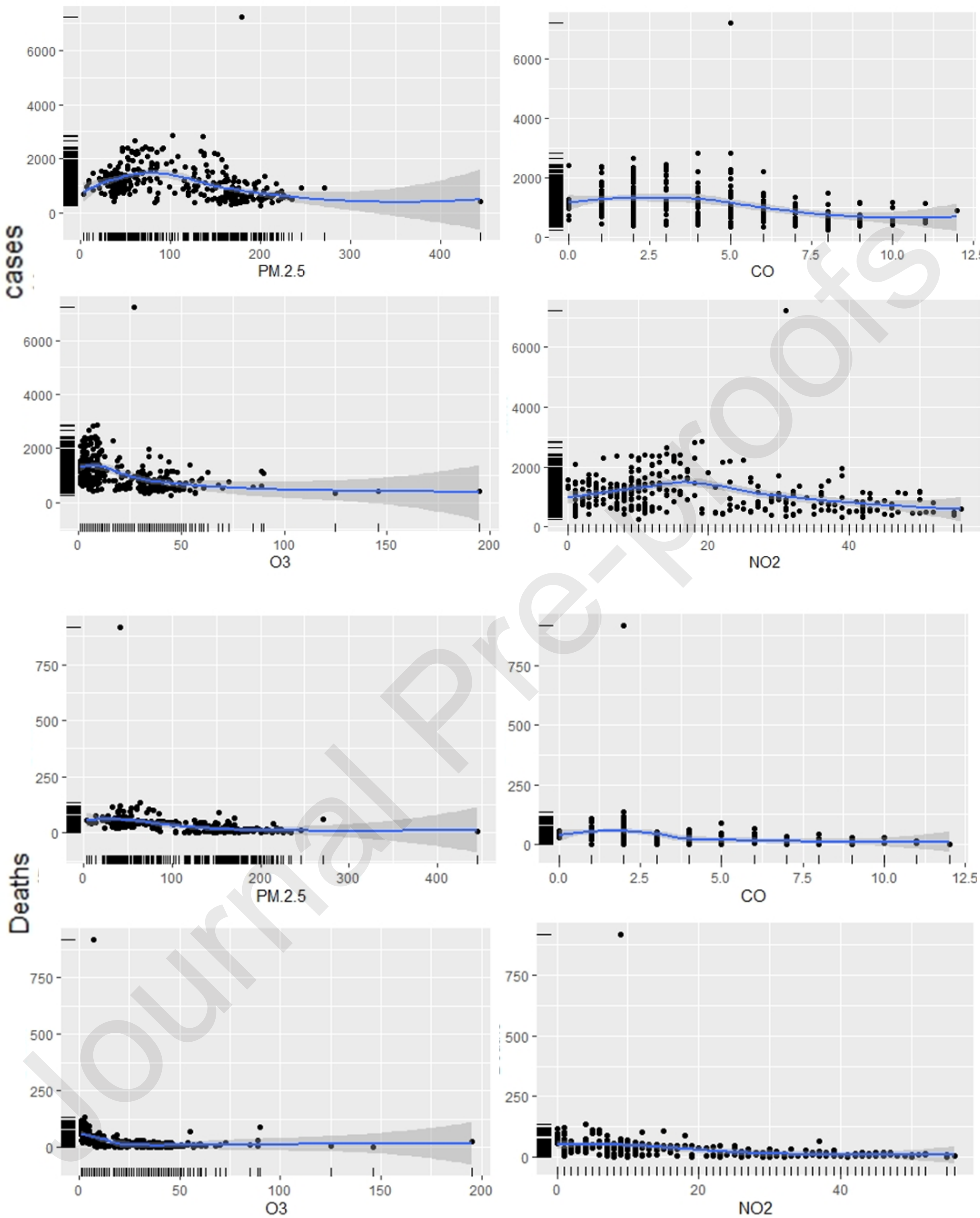

Fig. 2. Association of PM2.5, CO, O3 and NO2 with SARS-CoV-2 cases and deaths in Mumbai.

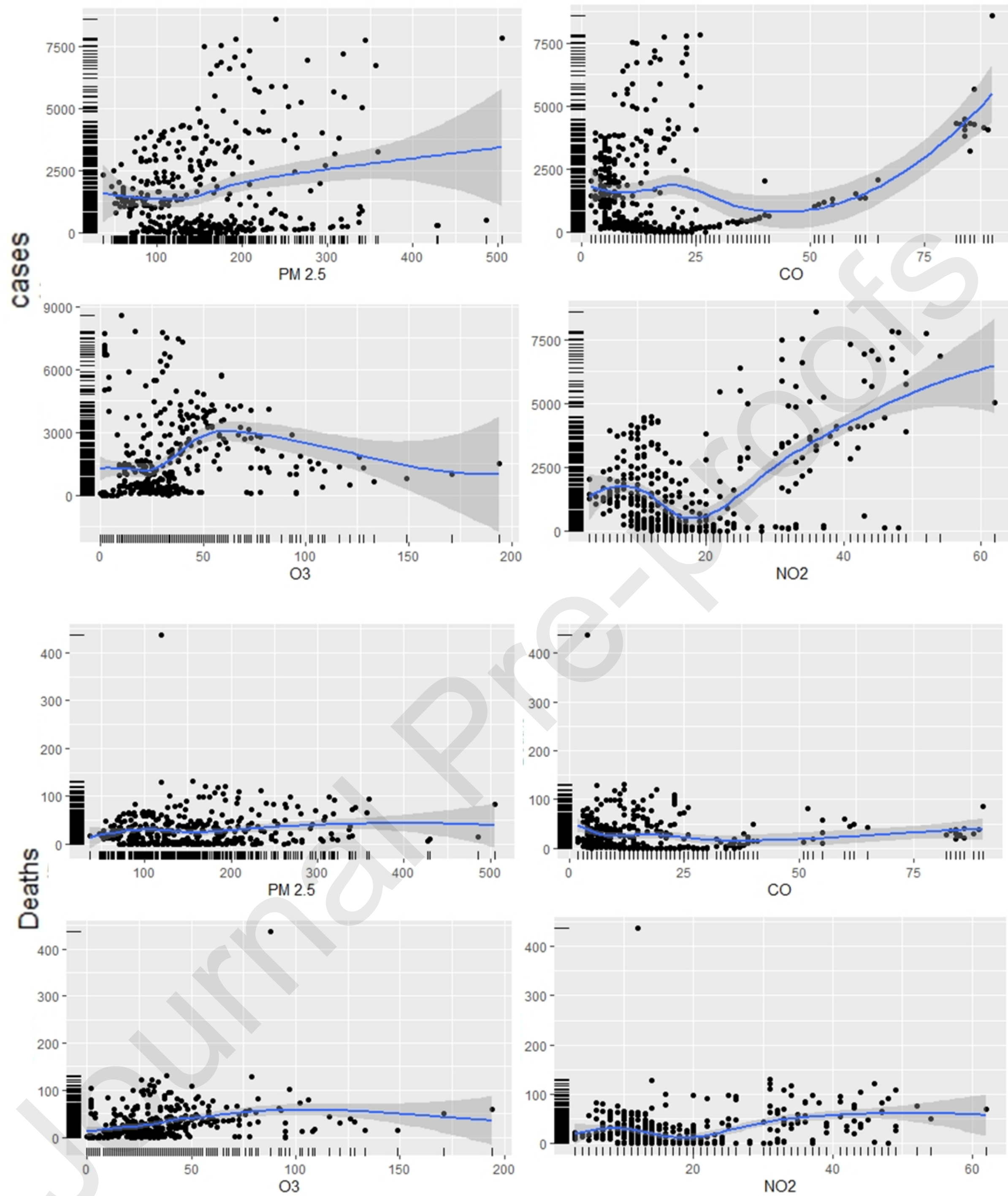

Fig. 3. Association of PM2.5, CO, O3 and NO2 with SARS-CoV-2 cases and deaths in Kolkata.